REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE

August 1997

3. REPORT TYPE AND DATES COVERED

Final Report

4. TITLE AND SUBTITLE

The Investigation Of The The Mechanism For Excitation Of Metastable States Of Nuclei During Inelastic Scattering Reaction Of γ-Quanta On The Nuclei

5. FUNDING NUMBERS

F6170896W0252

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8. PERFORMING ORGANIZATION REPORT NUMBER

N/A

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

EOARD
PSC 802 BOX 14
FPO 09499-0200

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

SPC 96-4036

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

A

13. ABSTRACT (Maximum 200 words)

This report results from a contract tasking Uzhgorod State University as follows: The contractor will investigate the mechanisms for excitation of metastable states of nuclei as described in his proposal.

14. SUBJECT TERMS

Physics, Lasers

15. NUMBER OF PAGES

30

16. PRICE CODE

N/A

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19, SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

SPC-96-4036

THE INVESTIGATION OF THE MECHANISM FOR EXCITATION OF METASTABLE STATES OF NUCLEI DURING INELASTIC SCATTERING REACTION OF γ-QUANTA ON THE NUCLEI

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Report Special Project SPC-96-4036 of Contract
F61708-96-W0252, Notic of Contract Award

In present report, analysis data about the activation levels in nucleus $^{107,109}_{47}Ag_{60,62}$, $^{111}_{48}Cd_{63}$, $^{113,115}_{49}In_{64,66}$ and $^{199}_{80}Hg_{119}$, obtained in reaction (γ,γ'), together with the data about one-nucleon transfer reactions, are carried out. Experimental and theoretical investigations of $^{89}_{39}Y_{50}$ isomer state excitation within the energy range of 7 - 9.5 MeV using the beam of bremsstrahlung at the microtron available at the Nuclear Physics Chair of the Uzhgorod State University.

The shell configurations of transitions from the $^{107,109}_{47}Ag_{60,62}$, $^{111}_{48}Cd_{63}$, $^{113,115}_{49}In_{64,66}$ and $^{199}_{80}Hg_{119}$ nuclei groun state to the activation levels, corresponding to one-nucleon transitions between the subshells within the upper unfilled 2p1f1g- and 1h2f3p1i-shell, are determined.

Using bremsstrahlen beam of microtron, the integral cross section excitation of isomerical states of $^{89}_{39}Y_{50}$ in (γ,γ') reaction in the energy region 7-9.5 MeV have been measured. The activation level near the ~8.5 MeV energy in $^{89}_{39}Y_{50}(\gamma,\gamma')^{89m}_{39}Y_{50}$ reaction was detected. The analysis of these results in the approaching between the proton subshells: not full 2s1f1g - shell and empty 2d3s1g1h - shell was realized.

INTRODUCTION

New interest to the studies of excitation of isomeric nuclei in the reaction of γ-quanta inelastic scattering by atomic nuclei has been resumed, mostly in studying the nuclei isomeric states excitation mechanism, which is to a certain degree related to the problem of γ-lasers [1].

The present report is aimed at attracting attention to the possibility of an atomic nucleus to be described by one-nucleon transitions,using the information from the one-nucleon transfer reactions.

We begin with the main regularities, having been revealed at the experimental studies of metastable states excitation in the reaction of γ-quanta inelastic scattering by atomic nuclei within the energy range below 25 MeV.

The studies of nuclei isomeric states excitation at the reaction of γ-quanta inelastic scattering by nuclei have been carried out already for about 55 years since the pioneer papers [2,3], vast experimental data having been accumulated. A review [4],containing more thun 110 references, is devoted mainly to the investigation of the nuclei isomeric states excitation at the γ-quanta energy below 3 MeV. $A(\gamma,\gamma')^{m}A$ reaction in the energy range of 4 to 20 MeV was studied in refs. [5-12]. New results of the nuclei isomeric states excitation at $A(\gamma,\gamma')^{m}A$ reaction in the energy 1,5 to 7MeV in [13-20] and $A(\gamma,\gamma')^{m}A$ reaction absolute cross-sections at the energies 4 to 14 MeV [21 - 27] have been obtained recently. A number of papers [28-31] is devoted to the studies of short-lived isomeric states excitation at $A(\gamma,\gamma')^{m}A$ reaction in the range of energies from 3 to 6 MeV.

In the nuclear reactions, induced by photons with the energies below 30 MeV, the main role can be played only by E1, E2 and M1 transitions, while the isomeric transitions mostly belong to E3, M4, M5 type, this evidently implying the low probability of the nucleus isomeric state excitation by γ-quanta (the problem of the nuclei isomeric states direct excitation by Mossbauer effect is discussed in [32]). Therefore, the nucleus isomeric state excitation occurs of follows. A level (usually called the activation level, energetically higher than the metastable one) is excited, for which the probability of the transition to the metastable level is comparable with that of the transition to the ground state. Thus the deexcitation of the activation level results in the isomeric state excitation.

The experimental studies of γ-quanta inelastic scattering by nuclei, having been carried out, can be classified into several groups:

(a) determination of the principal possibility of the isomers to be activated;

(b) determination of the activation level energies, widths and the activation cross-sections;

(c) plotting the $A(\gamma,\gamma')^{m}A$ reaction cross-section of absolute vs the γ-quanta energy;

(d) plotting the $A(\gamma,\gamma')^{m}A$ reaction integrated cross-section vs the γ-quanta energy;

(e) applications of the γ-quanta inelastic scattering in γ-activation analysis of materials and γ-radiation monitoring.

It should be noted that the data, obtained from the experiments on the γ-quanta inelastic scattering by nuclei, combined with the results obtained by other techniques of the nuclei excitation (e.g. one-nucleon transfer reactios), can give important information on the nucleus energy levels structure and the transition multipolity.

The studies of the nuclei metastable states excitation in (γ,γ') reaction have revealed the metastable states to be populated via the separate activation levels of the nucleus [29-31, 33-38], the metastable state excitation cross-sections within the energy range of 3 to 7 MeV being by 2 to 3 orders of magnitude higher then those below 2.5 MeV. Besides, in [27] the isomeric cross-section ratio in the (γ,γ') reaction (i.e. the ratio of the metastable state excitation cross section in the $A(\gamma,\gamma')^{m}A$ reaction to the total photoabsorption cross-section) was noticed to be sensitive to the metastable state shell structure.

The issue on the second maximum in $A(\gamma,\gamma')^{m}A$ reaction cross-sections for ^{89}Y, ^{105}Rh, ^{109}Ag, ^{197}Au, revealed in [6-9] at the energies near 20-22 MeV,at present still remains open. The nature of the maximum was discussed in [39] in the framework of the shell model of nuclei and is supposed to be related to the isobar analog resonances, in particular, with 2p-2h excitations.

As noted above, the metastable states in $A(\gamma,\gamma')^{m}A$ reaction are populated via the higher-energy excited levels of the nucleus, therefore, the issue on the metastable state population mechanism is reduced to the nuclear levels excitation mechanism.

At the interaction of γ-quanta with atomic nuclei the nuclear levels excitation occurs either due to photoabsorption (i.e. via the giant dipole resonance states), or at the γ-quanta in elastic scattering.

Within the discussed range of the excitation energies below 3 MeV we have a discrete spectrum of excited nuclear levels. In this case the γ-quanta inelastic scattering is the main channel of the nucleus excitation.

In the approximation of one resonant level the probability P of exciting an isomeric level is determined by

$$P=\Phi(E_r)\sigma_r(E_r) \qquad (1)$$

where

$$\sigma_r(E_r) = g(\lambda/4\pi)\Gamma_m \Gamma_o /\Gamma$$

The parameters g, Γ_o, Γ_m and Γ are, respectively, the statistical weight, the ground state transition width of the resonance level, the partial width for decay to the isomeric level, and the total width of the resonance level. λ is the wavelength of the γ-quanta which excite the resonance level at the energy E_r. $\Phi(E_r)$ is the flux of photons per unit area energy.

The analysis of the experimental studies of metastable states excitation in the range of isolated levels, i.e. via the activation states, is based on the Eq.(1) expression.

At present there are some indications [41-43] of the presence of nonresonant processes at the nuclei metastable states excitation by isotopic source

In this view the paper of Batkin [45] should be mentioted. Evidently it seems to be a single paper where are the mechanism of the nuclear levels non-resonant s of γ-quanta. The same issue was discussed in [44]. excitation is proposed. This mechanism is similar to the Compton effect, only instead of the γ-quantum scattering the nucleus excitation occurs. In [45] such process is called the nucleus Compton excitation.

I. SIGNIFICANCE OF THE PROBLEM

In the article (V.P.Aleshin and V.I.Kirischuk. The size of stimulated γ-ray emission cross section. First International Gamma-Ray Laser Workshop, GARALAS'95), the attention is paid to the fact that while deriving the formula to calculate the size of stimulated γ-ray emission (see e.g. G.C.Baldwin, e.a., Rev.Mod.Phys.,53(1981), 4(1),687), the approximation has been used which in case of the uclear system contrary to the analysis carried out by Einstein is omehow not correct as in this case the equilibrium may in reality be short in time due to the presence of an inelastic hole connected with internal conversion. That's why V.P.Aleshin and V.I.Kirischuk considered the process of γ-ray emission stimulation as $(\gamma,2\gamma')$-reaction within the frame of S-matrix method. In this method it is necessary to have an information about proper wave functions $\psi(1)$ and $\psi(2)$ of initial (1) and final (2) states of the nucleus. These wave functions depend greatly on the nucleus model chosen and on the mechanism of the interaction proposed between γ-quanta and an atomic nucleus.

Conducting a joint analysis of the data obtained on the excitation of metastable states in nuclei during (γ,γ')reaction with the data obtained from one-nucleon transfer reactions as shown in the article (Dzjamko V.S., Sokolyuk I.V.,Zajac T.M.,Mechanism for excitation of metastable levels by (γ,γ') reactions,First International Gamma-Ray Laser Workshop,GARALAS'95, Hyperfine Interaction 107 (1997) 175-183) allows one to get the information about the mechanism of the interaction between γ-quanta and atomic nuclei. Such data allow one to use S-matrix method in order to describe cross section of stimulated γ-ray emission more precisely,they will also help to choose the most suitable nucleus in order to carry out the experimental investigations in this regard.

In present report, analysis data about the activation levels in nucleus $^{107,109}_{47}Ag_{60,62}$, $^{111}_{48}Cd_{63}$, $^{113,115}_{49}In_{64,66}$ and $^{199}_{80}Hg_{119}$, obtained in reaction A(γ,γ')^{m}A together with the data about one-nucleon transfer reactions, are carried out. Experimental and theoretical investigations of $^{89}_{39}Y_{50}$ isomer state excitation within the energy range of 7 - 9.5 MeV using the beam of bremsstrahlung at the microtron available at the Nuclear Physics Chair of the Uzhgorod State University.

II. THE STRUCTURE OF THE ACTIVATION LEVELS, OBSERVED IN (γ,γ') REACTION

The analysis of photonucleon reactions, performed in [46-48], indicated the correlation of partial photoproton cross-sections of population of the finite nuclei lower excited states with the pick-up reactions data. In [49,50] the correlation of (e,e'p) and (d,t)reactions for the closed-shell nuclei was also indicated. The correlation of cross-sections in (γ,n) reaction is also indicated in [51]. Such correlation probably enables to make the choice in favour of the one-nucleon mechanism of the γ-quanta interaction with the atomic nucleus, at least for the near-megic nuclei.

Recently in [52] a positive correlation between the excitaion of ^{15}N and ^{39}K nuclei hole states,excited in (γ,γ') and (d,t) reactions.

The analysis of the data obtained on the excitation of metastable states of nuclei during (γ,γ') reaction and the information received from one-nucleon transfer reaction allows one to get the information about the excitation mechanism of activation levels [53].

This part of the report will be devoted to the analysis of (γ,γ') reactions with the excitation of $^{107,109}_{47}Ag_{60,62}$, $^{111}_{48}Cd_{63}$, $^{113,115}_{49}In_{64,66}$ and $^{199}_{80}Hg_{119}$ nucleis and the data from the one-nucleon transfer reactions.

Theoretical and experimental interest to $^{107,109}_{47}Ag_{60,62}$, $^{111}_{48}Cd_{63}$, $^{113,115}_{49}In_{64,66}$ nuclei is explained by the presence of valency protons and neutrons on different subshells of outermost unfilled sheells of these nuclei. In accordance with the shell-like model,

neutron *1g2d3s1h* - shell. For complete population of the proton shell of these nuclei two or even one proton are needed. That is, only proton subshell $1g_{9/2}$ is populated. The structure of proton *1f2p1g* - shell will be considered in detail below. The number of neutrons in nuclei under examination changes from 60 to 66. In work [40] the attention was paid to probable magicity of number 64. The magicity of one of shells (proton or neutron one) is shown to influence the structure of other shell. In this case one may expect that this will influence the population mechanism of isomeric states for the given nuclei.

Within the shell-like model the ground state of magic nuclei corresponds to the system of non-interacting nucleons which populate discrete states from the self-coordinated field bottom to Fermi level. Simple excited states of magic nuclei (in the case of semi-populated shells the situation is complicated at the expense of matching forces) are formed by the way of throwing one nucleon from a filled shell over vacant one. During this process under Fermi level a hole is formed, and over it - a particle (see Fif.1).

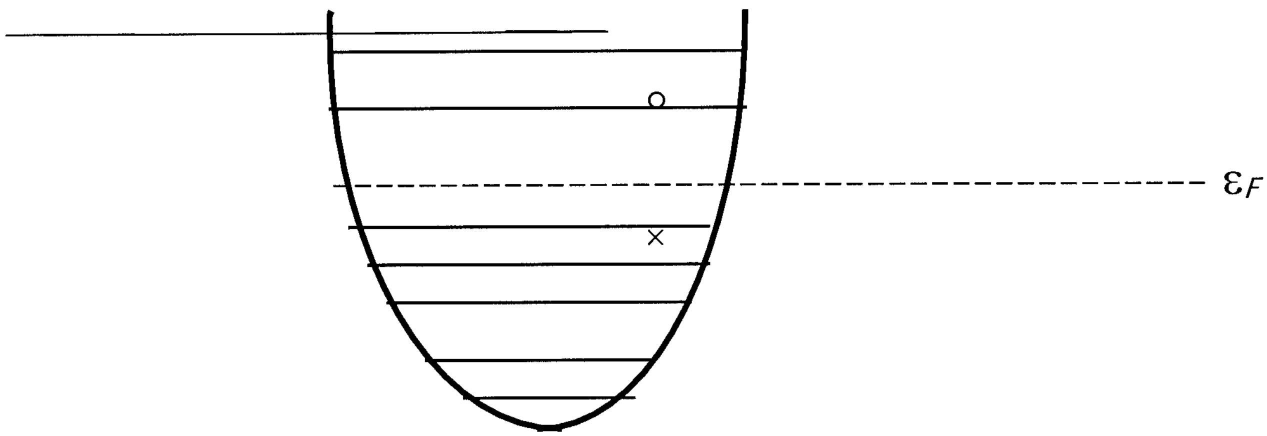

Fig.1.Particle-hole excitations in a potential well. Fermi level separates vacant and populated states.

The best way to check one-particle states lies in the study of nucleon transfer reactions, for example (p,d) - or (d,p) - reactions. From such reactions the energies of one-particle (one-hole) states are simultaneously determined. The probability to capture a nucleon from an impinging particle (stripping reaction, (d,p) type) by a nucleus into one-quasiparticle state is proportional to the numbers of vacant sites in this state (a certain subshell), and the probability to break a nucleon away by an impinging particle (pick-up reaction of (p,d) type) in proportional to the number of particles in this state.

The information about shell-like structure of nuclei is obtained in one-nucleon transfer reactions (that is in stripping and pick-up reactions). Such reactions are considered to be "surface"reactions. As it was mentioned, the study of partial photonuclear reactions showed that the correlation is observed between the structure in cross-sections and spectroscopic factors from one-nucleon transfer reactions. This fact may explain why we consider the photonuclear reaction like "surface" reaction. That is why comparing the levels (according to the scheme shown in Fig.2.) which are observed in stripping, in γ-quanta inelastic scattering and pick-up reactions that result in the formation of one and the same nucleus, one may obtained the information about the structure of levels to be observed in γ-quanta inelastic scattering reaction.

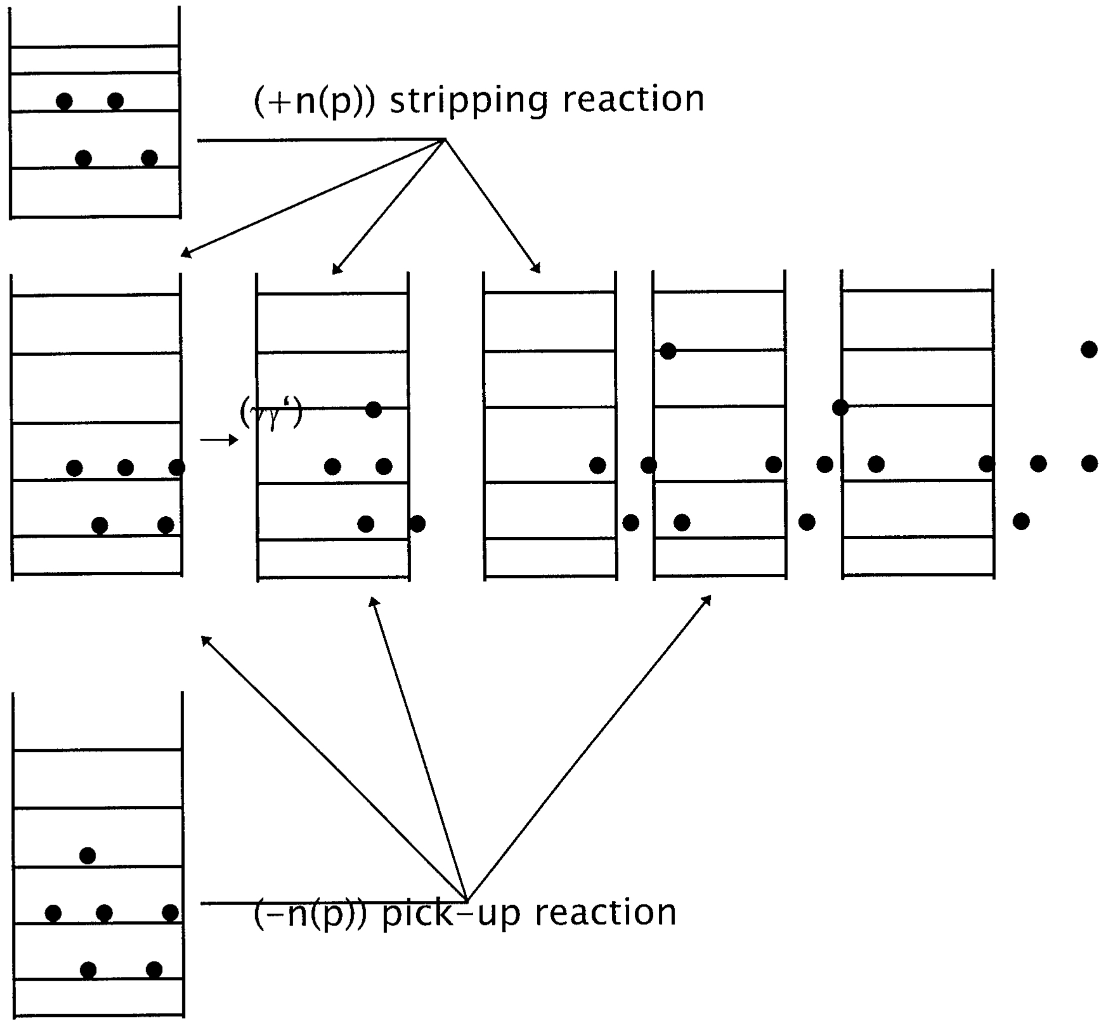

Fig. 2. Final states of the residual nucleus in a closed-shell target by stripping, γ-quanta inelastic scattering and pick-up reactions, respectively.

2.1. $^{109}_{47}Ag_{62}$ - NUCLEUS

The investigation of excited states of $^{109}_{47}Ag_{62}$ nucleus has been carried out in [54-56] in one-proton transfer reactions [54,55] ,in inelastic scattering reaction and others. The systematization of excited levels has been conducted in [56]. The scheme of levels of $^{109}_{47}Ag_{62}$ nucleus is given in table 1 In this table spectroscopic characteristics which were obtained in one-proton transfer reactions, energies E^a of activation levels observed in γ-quanta inelastic scattering reaction are given and the levels which result in the population of metastable state of $^{109}_{47}Ag_{62}$ are denoted by sign (*). The metastable state is a collective state formed as a result of interaction of a hole in $1g_{9/2}$ subshell and quadrupolar phonon of $^{110}_{48}Cd_{62}$ core.

From table 1 it is seen that activation levels which are observed in γ-quanta inelastic scattering reaction correlate with corresponding levels to be observed in one-proton pick-up reaction.

Table 1. Spectrocopic characteristics of levels for $^{109}_{47}Ag_{62}$ nucleus.

E, keV	J^{π}	Γ_m/Γ	$^{110}_{48}Cd_{62}$ (d,^{3}He)			$^{108}_{46}Pd_{62}$ (^{3}He,d)			E^a,keV [36]	configuration of transitions
			l	*nlj*	S^-	*l*	*nlj*	S^+		
0	$1/2^-$		1	$2p_{1/2}$	1.3	1	$2p_{1/2}$	0.86		
88	$7/2^+$								metastable	
132	$9/2^+$	*	4	$1g_{9/2}$	5.6	4	$1g_{9/2}$	2.4		
311	$3/2^-$		1	$2p_{3/2}$	0.8	1	$2p_{3/2}$	0.43		
415	$5/2^-$	*	3	$1f_{5/2}$	**	(3)		≈0.2	410±10	$3f_{5/2}\rightarrow 2p_{1/2}$
701	$3/2^-$	*	1	$2p_{3/2}$	0.6				680±30	$3p_{3/2}\rightarrow 2p_{1/2}$
707	$1/2^+$					0	$3s_{1/2}$	0.29		
724	$3/2^+$	*								
735	$5/2^+$	*	2	**	0.2	2	$2d_{5/2}$	1.9		
862	$5/2^-$	*	3	$1f_{5/2}$	0.7				855±5	$3f_{5/2}\rightarrow 2p_{1/2}$
869	$5/2^+$	*				2	$2d_{5/2}$			
890	$9/2^+$		4	$1g_{9/2}$	0.7					
911	$7/2^+$	*				4		2.7		
1091	$(9/2)^-$									
1098	$(5/2)^+$									
1210	$(9/2)^+$		4	$1g_{9/2}$	0.5				1210±10	$1g_{9/2}\rightarrow 2p_{1/2}$
1260	$(1/2)^-$					(1)		0.2		
1324	$3/2^-$	*	1	$2p_{3/2}$	0.7					
1430	$(1/2^+)$					0		0.03		

0										
1500	$3/2^-$		1	$2p_{3/2}$	0.4				1480±10	$2p_{3/2} \to 2p_{1/2}$
1524	$(3/2)^-$									
1599										
1613	$(1/2)^-$									
1658	$(1/2)^+$					0	$3s_{1/2}$	0.2	1675±10	$2p_{1/2} \to 3s_{1/2}$
1736	$(3/2)^-$									
1792	$(7/2)^-$									

The experimental data from one-proton transfer reactions show that the ground level of ${}^{109}_{47}Ag_{62}$ is a hole in $1p_{1/2}$ subshell. Shell-like structure of the ground state and the first excited states of ${}^{109}_{47}Ag_{62}$ nucleus is given in fig.3. From fig.3 it is seen that in the ground state ${}^{109}_{47}Ag_{62}$ nucleus has one proton (or hole) on $2p_{1/2}$ subshell, $2p_{3/2}$, $1f_{5/2}$ subshells are completely filled and on $1g_{9/2}$ subshell there are 8 protons. The excited state with the energy of 132 keV and $9/2^+$ spin is a hole in $1g_{9/2}$ subshell. For this state $1p_{1/2}$ subshell is completely filled. Similar situation is in other subshells.

${}^{78}Se(p,d) \to {}^{77}Se$ ground, $1p_{1/2}$ 250 keV, $1f_{5/2}$ 520 keV, $2p_{3/2}$

$2p_{1/2}$ —●●——— N=50 —●O——— —●●——— —●●———

$1g_{9/2}$ —●●●●——— —●●●●——— —●●●●——— —●●●●———

$1f_{5/2}$ —●●●●●●— —●●●●●●— —●●●●●O— —●●●●●●—

$2p_{3/2}$ —●●●●——— —●●●●——— —●●●●——— —●●●O———

Fig.3a. Nucleus ${}^{77}Se$.(● - neutron, O - hole)

${}^{88}Sr(p,d) \to {}^{87}Sr$ ground, $1g_{9.2}$ 388keV, $1p_{1.2}$ 873keV, $2p_{3.2}$

$1g_{9/2}$ ●●●●●●●●●●● N=50 ●●●●●●●●●●O ●●●●●●●●●● ●●●●●●●●●●

$2p_{1/2}$ ●●——— ●● ——— ●O——— ●●———

$1f_{5/2}$ ●●●●●●— ●●●●●●— ●●●●●●— ●●●●●●—

$2p_{3/2}$ ●●●●——— ●●●●——— ●●●●——— ●●●O———

Fig.3b. Nucleus ${}^{87}Sr$ (● - neutron, O - hole)

${}^{110}_{48}Cd_{62}(d,{}^{3}He){}^{109}_{47}Ag_{62} \to$ ground, $2p_{1/2}$ 132keV, $1g_{9/2}$ 415keV, $2f_{5/2}$

$2p_{1/2}$ ●●——— Z=50 ●O——— ●●——— ●●———

$1g_{9/2}$ ●●●●●●●● ●●●●●●●● ●●●●●●●O ●●●●●●●●

$1f_{5/2}$	●●●●●●—	●●●●●●—	●●●●●●—	●●●●●O—
$2p_{3/2}$	●●●●——	●●●●——	●●●●——	●●●●——

Fig.3c. Nucleus $^{109}_{47}Ag_{62}$.(● - proton, O - hole)

$^{116}_{50}Sn_{66}(d,^{3}He)^{115}_{49}In_{66}$		ground,$1g_{9/2}$	336keV,$1p_{1/2}$	597keV,$2p_{3/2}$
$1g_{9/2}$	●●●●●●●●●●● Z=50	●●●●●●●●●●O	●●●●●●●●●●	●●●●●●●●●●
$2p_{1/2}$	●●——	●● ——	●O——	●●——
$1f_{5/2}$	●●●●●●—	●●●●●●—	●●●●●●—	●●●●●●—
$2p_{3/2}$	●●●●——	●●●●——	●●●●——	●●●O——

Fig.3d. Nucleus $^{115}_{49}In_{66}$. (● - neutron, O - hole)

Fig.3. Structure levels of . $^{77}_{34}Se_{43}, ^{87}_{38}Sr_{49}, ^{109}_{47}Ag_{62}, ^{115}_{49}In_{66}$ nuclei.

It means that for the excitation of activation level with the energy of 410 keV and $5/2^-$ spin (it is a hole in $1f_{5/2}$ subshell) the proton from $1f_{5/2}$ subshell should be transferred to $1p_{1/2}$ subshell. Similar situation is observed for other activation levels. The configurations of transitions are given in table 1.

The level with the 1658 keV - energy may be assigned to the activation level with the 1675+10 keV - level. According to the scheme of levels for given nucleus [57] in this region of energies there do not exist other states - candidates for the activation level.

2.2. ^{107}Ag - NUCLEUS

The experimental studiy of isomeric state excitation of $^{107}_{47}Ag_{60}$ - nucleus in γ-quanta inelastic scattering reaction showed [36] that in the energy region of in γ-quanta to 2 MeV the population of $^{107m}_{47}Ag_{60}$ isomer occurs via activation levels with the energies of 423±2, 780±5, 945±5, 1250±5, 1325±5 keV. Low-lying energy levels of $^{107}_{47}Ag_{60}$ - nucleus were studied in (^{3}He,d), (p,t), (^{14}N,3nγ), (^{7}Li,4nγ), (p,p'), (d,d'). (n,nγ') reactions (see ENSDF file). In Table 2 we gave the scheme of energy levels obtained in these reaction and their spectroscopic characteristics obtained in one-proton stripping reaction. The levels which may result in the population of isomeric state of $^{107}_{47}Ag_{60}$ - nucleus are denoted by *. As it is seen from Table 2 the energy scheme of levels of $^{107}_{47}Ag_{60}$ - nucleus, the the same for In-nuclei, may be classified into three grous of levels. The first froup of levels may be described in the approximation of core-Pd plus proton. The second group of levels - in the approximation of a hole in core - Cd. The third group may be described in the

approximation of interaction between the particle or hole with the corresponding core.

Comparing the energy scheme of levels with the energies of activation levels, we see that the latter correlate with those levels which are observed in stripping reaction,, that is they have a simple one-particle nature. The structure of the fround state of ${}^{107}_{47}Ag_{60}$ is the same as of ${}^{109}_{47}Ag_{62}$ nucleus. So, the ground state is a hole in $1p_{1/2}$ subshell.

The first three activation levels with the energies of 423±2, 780±5, 945±5 keV correspond to hole states in subshells $1f_{5/2}$, $2p_{3/2}$ (see table 2). The configurations of transitions for the guven activation levels are given in Table 2. The activation levels with the enrgy of 1250±5, 1325±5 keV correspond to particle states on subshell $2d_{5/2}$. There is no possibility to define shell configurations of transitions onto these activation levels, since it is necessary to have the information about the shell structure of core ${}^{106}_{46}Pd_{60}$. Bat we may sey that these transitions are one-nucleon transitions from subshells *1f2p1g* - shell onto $2d_{5/2}$ - subshell. Proceeding from theabove, we caan draw a conclusion, that activation levels are formed at the expense of one-nucleon transitions between outermost unfilled subshells of ${}^{107}_{47}Ag_{60}$ - nucleus.

Table 2. Spectrocopic characteristics of levels for ${}^{107}_{47}Ag_{60}$ nucleus.

E, keV	J^{π}	Γ_m/Γ	$^{106}Pd(^{3}He,d)$			E^a,keV [36]	configuratin of transitions
			l	*nlj*	S^+		
0	$1/2^-$		1	$2p_{1/2}$	0.50		
93	$7/2^+$					metastable	
126	$9/2^+$	*	4	$1g_{9/2}$	1.46		
325	$3/2^-$		1	$2p_{3/2}$	0.19		
423	$5/2^-$	*	(3)	$1f_{5/2}$	0.056	423±2	$1f_{5/2} \rightarrow 2p_{1/2}$
773	$(11/2)^+$	*					
787	$3/2^-$	*	1	$2p_{3/2}$	0.15	780±5	$2p_{3/2} \rightarrow 2p_{1/2}$
922	$5/2^+$	*	2	$2d_{5/2}$	0.47		
950	$5/2^-$	*				945±5	$1f_{5/2} \rightarrow 2p_{1/2}$
	$(7/2)^-$	*					

973							
991	$(13/2)^+$	*					
1063	$7/2,9/2^+$	*	4	$1g_{9/2}$	0.19,0.10		
1142	$1/2^+$		0	$3s_{1/2}$	0.32		
1143	$(5/2)^-$	*					
1147	$(9/2)^-$	*					
1222	$11/2,13/2^-$						
1223	$(5/2)^+$	*	2	$2d_{5/2}$	0.82		
1258	$(3/2)^+$	*	2	$2d_{3/2}$	0.48	1250±5	$? \rightarrow 2d_{5/2}$
1326	$(3/2)^+$	*	2	$2d_{3/2}$	0.08	1325±5	$? \rightarrow 2d_{5/2}$
1449		*					
1465	$(3/2)^-$		(1)	$2p_{3/2}$			
1483							
1508	$7/2,9/2^+$		4	$1g_{9/2}$	1.52,0.77		
1572	$7/2,9/2^-$						
1577	$(15/2)^+$						
1615	$1/2^-$						
1653	$1/2^-$						
1656	$7/2,9/2^+$		4	$1g_{9/2}$	0.30,0.16		

2.3. $^{111}_{48}Cd_{63}$ - NUCLEUS

In work [36], by using the beam of electrons (with the energy up to 3 MeV) and γ-quanta the excitation of $^{111}_{48}Cd_{63}$ - nucleus isomeric state was studied. As a result three activation levels with the energies of 740 ±10 keV, 1120±10 keV and 1330 ±10 keV were revealed. Low-lying levels of this nucleus were also studied in (n,γ), (n,n'γ), (α,3nγ), (^{3}He,2nγ), (p,p'), (d,d'), (d,p), (d,t) reactions. The energy scheme of levels otained in these reactions is given in Table 3. In the same table spectroscopic information of levels is given which is obtained in the reactions of one-nucleon transfer reactions and the energy of activation levels that are observed in $(\gamma,\gamma')^m$ reaction (the data are take from ENSDF file). In accordance with the shell-like model, there must be filled neutron $2d_{5/2}$- and $1g_{7/2}$ - subshell in $^{111}_{48}Cd_{63}$ - nucleus. As it is seen from the table 3 neutrons are scattered over $2d_{5/2}$ -, $1g_{7/2}$-, $3s_{1/2}$-, $1h_{11/2}$-, $2d_{3/2}$-subshells of *1g2d3s1h* - shell. This may be the result of neutron *1g2d3s1h* - shell influence, on which the number of neutrons is close to number 64 being a pretendent to magic namber [36].

From the table 3 it is seen that there is no unanbiguons correspondence between energies of activation levels and levels to be observed in reactions of other type. In accordance with experimental data (ENSDF file) levels with the energies of 681 , 705, 831, 968, 1151, 1339 keV (in table 3 they are denoted by - *) may be pretendents to activation levels.

In the energy region of the first activation level with the energy of 740±10 keV in accordance with γ-decay scheme the level with the energy of 705 ± 10 keV (J^π = $7/2^+$) is the pretendent to actovation level. This level via the level with the energy of 681 keV (J^π = $9/2^-$) results in the metastable level population. In this energy level there is the level with the energy of 736 keV which is observed in inelastic scattering reaction of protons and deutrons only. But in accordance with experimental data (ENSDF file) it does not populate metastable state.

The level with the energy of 705 ± 10 keV (J^π = $7/2^+$) to which we asssign the activation level with the energy of 740 ± 10 keV observed in $(\gamma,\gamma')^m$ reaction is noticed in one-nucleon transfer reactions ((d,t), (d,p)). It follows from this reaction that it is formed by $1g_{7/2}$ subshell. It means that the given activation level is formed by one-nucleon transittion from more low-lying subshell (to give a specific information about the configuration of the given transition one needs experimental information about the shell structure of the ground state of $^{111}_{48}Cd_{63}$ - nucleus) onto subshell $1g_{7/2}$. But we can say that the given activation level is formed at the expense of one-nucleon transition.

In the energy region of the second activation level with the energy of 1120±10 keV the level with the energy of 1151±10 keV is the pretendent to the activation level (which via the level with the energy of 705 keV results in the population of metastable state of $^{111}_{48}Cd_{63}$ - nucleus). In this energy region in one-nucleon transition reaction the level with the energy of 1130±10 keV is observed which is formed by $2d_{5/2}$ subshell. This level in accordance with the data (ENSDF file) is observed in the given reaction only, therefore we identify these two levels as one level with the energy of 1151±10 keV and spin J^π = $5/2^+$. To, the given activation level is also formed at the expense of one-nucleon transition onto neutron subshell

due to the absence of information about the shell structure of the ground state of ${}^{111}_{48}Cd_{63}$ - nucleus.

The next activation level is observed at an energy of 1330±10 keV. In this energy region the level with the energy of 1339 keV ($J^{\pi} = 15/2^{-}$) is the pretendent to the activation level which results in the population of metestable state of ${}^{111}_{48}Cd_{63}$ - nucleus.

This level is observed in (α,3nγ) and (^{3}He,2nγ) reactions. It belongs to the band built on isomeric state with the energy of 396 keV ($J^{\pi} = 11/2^{-}$). In order to populate this level from the ground state with spin $1/2^{+}$ it is necessary to perform γ-transition of M6 or E7 - multipoles that is very improbable. We think thaat the given level is formed at the expense of the interaction between γ-quanta and neutrons of $1h_{11/2}$ - subshell.

So, we can draw a conclusion that activation levels are formed at the expense of one-nucleon transitions within ontermost *1g2d3s1h* - shell.

Table 3. Spectrocopic characteristics of levels for ${}^{111}_{48}Cd_{63}$ nucleus.

E, keV	J^{π}	Γ_m/Γ	^{112}Cd(d,t) ^{110}Cd(d,p)		E^a,keV [36]	configuration of transitions
			l	*nlj*		
0	$1/2^{+}$		0			
245	$5/2^{+}$		2			
342	$3/2^{+}$		2			
396	$11/2^{-}$		5			
417	$7/2^{+}$		4			
620	$5/2^{+}$		2			
681	$(9/2)^{-}$	*				
705	$7/2^{+}$	*	4		740±10	? → $1g_{9/2}$
736	$3/2,5/2^{+}$					
753	$5/2^{+}$					
755	$3/2^{+}$					
831	$(7/2^{-})$	*				
854	$7/2^{+}$					
856	$3/2^{+}$					
865	$3/2^{+}$		2			
867	$3/2^{+}$					
968	$15/2^{-}$	*				
986	$9/2^{+}$					
1017	$3/2^{+}$					
1020	$1/2^{+}$		0			

1047	(7/2+)					
1057						
1078	3/2+					
1116	3/2+					
1118	3/2+					
1130			2		1120 ±10	? → $2d_{5/2}$
1151	(5/2+)	*				
1186	1/2+		0			
1190	3/2+					
1257	11/2+					
1275	(5/2+)					
1289						
1299	(7/2+)					
1322						
1326	1/2,3/2 +					
1340	(13/2-)	*			1330 ±10	
1341	1/2,3/2					

2.4. $^{115}_{49}In_{66}$ - NUCLEUS

The experimental data available about low-lying levels of nuclei for odd (unpaired) isotopes can't be explained by proton-hole excitations in closed subshell Z=50.To explain the properties of these levels it seems to be necessary to take into account definite configurations of proton shell (50-82). The most successful approximation [58,59] is obtained if one considers a full set of basic functions that consist of hole-type excitations in Sn core and states of particle-type state with Cd core. This idea was developed in work [60].

The excited states of $^{115}_{49}In_{66}$ nucleus were studied in different reactions. In

Table 4 . Spectrocopic characteristics of levels for $^{115}_{49}In_{66}$ nucleus.

E, keV	J^{π}	Γ_m/Γ	^{114}Cd(^{3}He,d)			^{116}Sn(d,^{3}He)			E^a,keV	configuration of transitions
			l	*nlj*	S^+	*l*	*nlj*	S^-		
0	9/2$^+$		4	$1g_{9/2}$	0.9	4	$1g_{9/2}$	7.4		
336	1/2$^-$		1	$2p_{1/2}$	0.14	1	$2p_{1/2}$	1.7		
597	3/2$^-$	*	1	$2p_{3/2}$	0.15	1	$2p_{3/2}$	2.0	600±10	$2p_{3/2} \rightarrow 1g_{9/2}$
829	3/2$^+$	*	2+0	$3d_{3/2}$	0.3+0.3				830±10	2g $\rightarrow$ 2d
864	1/2$^+$	*								
934	7/2$^+$	*	4+2		8.5+0.86	*			932±2	2p $\rightarrow$ 1g
941	5/2$^+$	*							943±2	2g $\rightarrow$ 2d
1041	5/2$^-$	*				3	$1f_{5/2}$	0.7		
1078	5/2$^+$	*				*			1078±3	2p $\rightarrow$ 2d
1132	11/2$^+$									
1192	(3/2)	*								
1287	1/2,3/2, 5/2$^-$	*				*				
1290	13/2$^+$									
1347	(5/2$^-$)	*								
1418	(9/2)$^+$	*								
1449	9/2$^+$	*	4	$1g_{9/2}$	0.32	4	$1g_{9/2}$	1.2		
1463	7/2$^+$	*								
1470	1/2,3/2$^-$					1	2p	0.3	1465±5	$2p_{3/2} \rightarrow 1g_{9/2}$
1478		*								
1486	9/2$^+$					4	$1g_{9/2}$	1.7		
1497	(7/2$^+$)	*							1495±5	

									1565±10	
1602	(7/2$^+$)									
1609	(7/2$^+$)	*								
1640	1/2,3/2$^-$					1	2p	0.4	1635±15	$2p_{3/2} \rightarrow 1g_{9/2}$
1650	3/2$^+$		2	$2d_{3/2}$	0.5,0.65					
1737	(9/2$^+$)		*							

nucleus obtained in one-proton transfer reaction and activation levels revealed in γ-quanta inelastic scattering reaction are given [36,37,61,62]. As it is seen from table 4 the levels to be observed in proton pick-up reaction and assigned to holes in $2p_{3/2}$ subshell correspond to activation levels with the energies of 600 keV, 1465keV and 1635 keV. Taking into account the shell-like structure of $^{115}_{49}In_{66}$ ground state (see fig.3) and the data of excited levels these activation levels are formed as a result of $2p_{3/2} \rightarrow 1g_{9/2}$ proton transition.

From table 4 it is seen that levels with 3/2$^+$, 5/2$^+$ and 7/2$^+$ spins and the first excited states are observed in proton stripping reaction on $^{114}_{48}Cd_{66}$ nucleus. It means that in this nucleus 2p-subshells are not completely filled and levels with 3/2$^+$, 5/2$^+$ and 7/2$^+$ spins in $^{115}_{49}In_{66}$ nucleus may be described as a particle with $^{114}_{48}Cd_{66}$ core. In this case the activation levels with 3/2$^+$, 5/2$^+$ and 7/2$^+$ spins may be described in the approximation of one-proton transitions to 2d or 1g subshells from 2p subshells. To obtain more unambiquous conclusions one needs the data on the probabilities of transitions obtained, from example, in Coulomb excitation and from γ-quanta inelastic scettering reaction. The nature of activation levels withh the energies of 1495 and 1565 keV remains unclear.

2.5. ^{113}In - NUCLEUS

The excitation of isomeric state of $^{113}_{49}In_{64}$ - nucleus in γ-quanta inelastic scattering reaction, in the energy region less than 2 MeV takes place via activation levels with the energies of 1.01., 1.13 and 1.58 MeV [35]. Besides, in work [35] the attention was paid to the presence of activation level in the region of energies less than 0.9 MeV.

The enrgy scheme of low-lying levels was studied in different reactions (see ENSDF file). The scheme of levels of $^{113}_{49}In_{64}$ - nucleus and the information obteined in stripping reactions (the data are taken from ENSDF file) are given in table 5. In the same table the levels from which the population of isomeric state of $^{113}_{49}In_{64}$ - nucleus is possible are denoted by sign (*). As it is seen from Table 5 the activation levels correlate with the levels observed in stripping reaction.

Proceeding from the scheme of levels, we ussing the level with the energy of 647 keV (J^{π} = 3/2$^-$) to the actovation level with the energy less than 0.9 MeV. The given level is a hole in subshell $2p_{3/2}$. Shell structure of the ground state of $^{113}_{49}In_{64}$ -

nucleus is the scheme as in ${}^{115}_{49}In_{66}$ - nucleus. Therefore we may assign the transition of type *$2p_{3/2} \rightarrow 1g_{9/2}$* to the given activation level.

Activation levels with the energies of 1.01 MeV and 1.13 MeV correspond to the level with the energies of 1.024 MeV (J^{π} = 5/2+) and 1.131 MeV (J^{π} = 5/2+), respectively. Sinse the given levels are observed in ${}^{112}_{48}Cd_{64}({}^{3}He,d){}^{113}_{49}In_{64}$ reaction, we may describe them in the model core (${}^{112}_{48}Cd_{64}$) + particle (proton on subshell *$2d_{5/2}$*). In order to define the shell configuration of the transition of proton onto subshell *$2d_{5/2}$* one needs detailed information about the shell structure of Cd core - nucleus. Bat the fact that the given activation levels are observed in one-proton stripping reaction speaks in favour of one-nucleon transition within outermost unfilled proton shell of ${}^{113}_{49}In_{64}$ - nucleus.

The activation level with the energy of 1.58 MeV may be identified with the level having the energy of 1.569 Mev. Sinse, in accordance with decay scheme it results in the population of metastable state, the given level is observed in (p,nγ) reaction and has twoness (-). Unfortunate, the information about pick-up reaction with the formation of ${}^{113}_{49}In_{64}$ - nucleus in this energy region is absent therefore there is no possibility to unambiguously identify the nature of the given level.

Proceeding from the above we may draw a conclusion in favour of one-nucleon transitions between subshell of the upper unfilled proton shell of ${}^{113}_{49}In_{64}$ - nucleus.

Table 5. Spectrocopic characteristics of levels for ${}^{113}_{49}In_{64}$ nucleus.

E, keV	J^{π}	Γ_m/Γ	${}^{112}Cd({}^{3}He,d)$			${}^{112}Cd(\alpha,t)$			E^a,MeV [35]	configuratin of transitions
			l	*nlj*	S^+	*l*	*nlj*	S^+		
0	$9/2^+$		4	$1g_{9/2}$	0.17	4	$1g_{9/2}$	0.15		
391	$1/2^-$		1	$2p_{1/2}$	0.059	1	$2p_{1/2}$	0.083		
647	$3/2^-$	*	1	$2p_{3/2}$	0.048	1	$2p_{3/2}$	0.078	<0.9	$2p_{3/2} \rightarrow 1g_{9/2}$
1024	$5/2^+$	*	2	$2d_{5/2}$	0.52	2	$2d_{5/2}$	0.30	1.01	$? \rightarrow 2d_{5/2}$
1029	$1/2,3/2^+$	*								
1064	$3/2^+$	*	2	$2d_{3/2}$	0.15	2	$2d_{3/2}$	0.090		
1106	$3/2,5/2^-$	*								
1131	$5/2^+$	*	2	$2d_{5/2}$	0.02	2	$2d_{5/2}$	0.021	1.13	$? \rightarrow 2d_{5/2}$
117	$11/2^+$									

1191	$7/2^+$	*	4	$1g_{9/2}$	0.21	4	$1g_{9/2}$	0.19		
1344	$13/2^+$									
1351										
1381	$1/2,3/2,5/2^-$	*								
1453										
1472	$3/2,5/2,7/2^-$	*								
1496		*								
1504										
1509	$7/2,9/2^+$	*								
1536	$1/2,3/2,5/2^-$	*								
1552										
1567	$7/2,9/2^+$		4	$1g_{9/2}$	0.03	4	$1g_{9/2}$	0.022	? 1.58	
1569	$(*)^-$	*							? 1.58	
1619		*								
1630	$(7/2,9/2^+)$	*								
1634			3,4		**	3,4	**			
1675		*								
1684		*								

2.6. $^{199}_{80}Hg_{119}$ – NUCLEUS

The $^{199}_{80}Hg_{119}$ nucleus excited states were studied in Ref. [35,36, 63 – 66] at (n,γ), (d,p), (d,t), (p,d) and (γ,γ') reactions. The energies of the excited states and their characteristics obtained in this papers, are listed in Table 6.

Only part of the levels, being observed in (n, γ),(d,p), (d,t), (p,d) reactions, are

(p,d) reactions, this fact meaning this subshell in the nucleus to be completely filled. Meanwhile, the $3p_{1/2}$, $3p_{3/2}$, $2f_{5/2}$, $2f_{7/2}$ subshells are manifested in (d,p) reaction, i.e. they are not completely filled.

Table 6. Spectrocopic characteristics of levels for $^{199}_{80}Hg_{119}$ nucleus.

E, keV	J^{π}	Γ_m/Γ	(d,t)			(d,p)			E^a,keV	configuration of transitions
			l	*nlj*	S^-	*l*	*nlj*	S^+		
0	$1/2^-$		1	$3p_{1/2}$	1.5	1	$3p_{1/2}$	0.46		
158	$5/2^-$		3	$2f_{5/2}$	2.4	3	$2f_{5/2}$	0.32		
208	$3/2^-$		1	$3p_{3/2}$	0.72	1	$3p_{3/2}$	0.20		
403	$3/2^-$		1	$3p_{3/2}$	1.1	1	$3p_{3/2}$	0.26		
414	$5/2^-$		(3)	$2f_{5/2}$	2.5					
455	$1/2,3/2^-$		(1)	3p	(0.04)					
492	$3/2^-$		(1)	$3p_{3/2}$	(0.04)					
532	$13/2^+$		6	$1i_{13/2}$	7.4					
638			?							
667	$5/2^-$		3	$2f_{5/2}$	0.31	(3)	$2f_{5/2}$	0.04		
669	$1/2,3/2$									
698	$5/2^-$		3	$2f_{5/2}$	0.74	(3)	$2f_{5/2}$	0.08		
737										
750	$3/2^-$		1	$3p_{3/2}$	0.13					
759						?				
822			?							
824	$(17/2^+)$									
969	$7/2^-$		3	$2f_{7/2}$	0.19				1000±20	$2f_{7/2} \rightarrow 3p_{1/2}$
1038										

4										
1226	$7/2,3/2^-$		3,1			3,1				
1269										
1274	$(15/2^+)$									
1319										
1329	$3/2^-$		1	$3p_{3/2}$	0.37	(1)	$3p_{3/2}$	0.03	1340±10	$3p_{3/2} \to 3p_{1/2}$
1357	$(21/2^+)$									
1360	1/2,3/2		?						1380±10	
1436	$3/2^-$		1	$3p_{3/2}$	0.27				1420±10	$3p_{3/2} \to 3p_{1/2}$
1454	$7/2,5/2^-$		(3)	$3f_{7/2}$	(2.7)	(3)	$2f_{7/2}$	0.04		
1519	1/2,3/2									
1561			?						1530±20	
1574	1/2,3/2									
1597	1/2,3/2		?							
1655	$3/2,1/2^-$		(1)	3p	(0.14)	(1)	$3p_{3/2}$	0.004		
1686			?						1700±20	
1733	1/2,3/2									
1746	1/2,3/2									
1782	1/2,3/2		?							

The analysis of the data on spectroscopic factors from the stripping and pick-up reactions for ^{200}Hg nucleus, obtained in the paper [65], using of the spin-dependent rule of sums [67], enabled the shell structure of the nucleus to be determined.

The model for population of the subshell upper 3p2f1i1h - shell of the ^{200}Hg are shown in Fig.4. The order in places of the subshells was chosen corresponding to the center of mass of excited level energies for the corresponding subshells (See table 7). Such order of the subshells agrees with the conclusion of Ref.[68] that in this range it is more energetically favourable to make the subshell $3p_{1/2}$ empty in order to make the subshell $1i_{13/2}$ completely filled. It also agrees with the calculations of Ref. [69], using the Nilsson's potential.

ground state-$3p_{1/2}$

```
----------------------------------  →(d,t)  ---------------------------
------
3p1/2   -●●----------------------   N=128   -●O----------------------
N=128
2f5/2   -●●●●--------------------           -●●●●-------------------
1i13/2  -●●●●●●●●●●●●●●-                  -●●●●●●●●●●●●●●-
3p3/2   -●●----------------------           -●●----------------------
2f7/2   -●●●●●●----------------             -●●●●●●----------------
1h9/2   -●●●●●●●●●●-------                 -●●●●●●●●●●---------
-------------------------------------       --------------------------
--------
                    N=82                            N=82
```

$^{200}_{80}Hg_{120}$ $^{199}_{80}Hg_{119}$

Fig.4. Scheme of the fill in the subshells 1h3p2f1i - shell of nucleus $^{200}_{80}Hg_{120}$ and the structure the ground state of the $^{199}_{80}Hg_{119}$, nucleus, where ● -neutron; O -hole in subslell.

Table 7.

nlj	$3p_{1/2}$	$2f_{5/2}$	$1i_{13/2}$	$3p_{3/2}$	$2f_{7/2}$
$\frac{\sum_i S^-(i)E(i)}{\sum_i S^-(i)}$, MeV	0.012	0.358	0.531	0.649*	1.381

*The energy of levels are forming by subshell $3p_{3/2}$ are meer at the two energies E_1 =0.356 MeV and E_2 =1.395 MeV.

It is seen from table 7 that the activation levels, observed in (γ,γ') reaction in Ref. [36] correspond within the error limits to the levels, observed in the neutron pick-up reaction Ref. [65].

The ground state of the $^{199}_{80}Hg_{119}$ nucleus is forming by the subshell $2p_{1/2}$,containing one neutron (or one hole). The shell structure of this nucleus is shown in Fig.4 according to the results of Ref.[65]. Thus in order to excite the activation level with the energy 1000+20 keV (corresponding to the 969 keV level, being the hole state of the $2f_{7/2}$ subshell),one should take one more neutron of the $2f_{7/2}$ subshell to the $3p_{1/2}$ subshell. That is why at the excitation of this activation level in the $(\gamma,\gamma')^m$ reaction a transition $2f_{7/2} \rightarrow 3p_{1/2}$ is realised. Similarly the transitions for other activation levels with energies 1340 + 10 keV, and 1420+10 keV corresponding to the 1325 and 1439 keV levels, being the $3p_{3/2}$ subshell hole states, can be determined.

These levels will correspond to $p_{3/2} \rightarrow p_{1/2}$ transition (see Table.6.). Unfortunately for the levels with the energies of 1561 and 1686 keV to which we assign the activation levels with the energies 1530+20 keV and 1770 +20 keV the corresponding transition configuration cannot be determined, because their shell structure has not been determined yet. But since they are observed in (d,t) reaction, this enables us to conclude that the similar transitions will exist for these levels. Thus, fromthe above judgements we may conclude that the activation levels for the $^{199}_{80}Hg_{119}$ nucleus at the energies below 2 MeV are to be formed due to the

III. THE EXCITATION OF ${}^{89}_{39}Y_{50}$ ISOMERIC STATE IN (γ,γ') REACTION IN THE 7 : 9.5 MeV ENERGY REGION

3.1. EXPERIMENTAL METHOD

The aim of this report is to investigate the excitation of isomeric state of ${}^{89}_{39}Y_{50}$ nuclei in (γ,γ') reaction within the 7 : 9.5 MeV energy region.

The yield of (γ,γ') reaction on ${}^{89}_{39}Y_{50}$ isotope were measured in a bremsstrahlung radiation beam of M-10 microtron at the Department of Nuclear Physics of Uzhgorod State University. The measurements were taken within the 7 - 9.5 MeV energy range with a step of 100 keV. The beam of a bremsstrahlung radiation was monitored with a thick-walled aluminium chamber used [70]. The target made of metal Y natural sample were used for measurements.

The scintillation NaJ(Tl)-detector recorded induced activity in samples. Isomers ${}^{89m}_{39}Y_{50}$ nuclei were identified by γ-lines of 909 keV. Spectroscopics of these γ-lines were taken from [58].

The yield of (γ,γ') reaction was calculated by the following equation:

$$Y(E_{\gamma\max}) = \frac{\lambda N_{\exp}(E_{\gamma\max}, t_{irr}, t_{cool}, t_{meas})}{\alpha\varepsilon\mu n D(E_{\gamma\max}) f(\lambda, t_{irr}, t_{cool}, t_{meas})}, \quad (2)$$

where α, ε, μ - quantum yield, recording efficiecy, coefficient of self-absorption for γ-quanta; $f(\lambda, t_{irr}, t_{cool}, t_{meas})=(1-exp(-\lambda t_{irr}))exp(-\lambda t_{cool})(1-exp(-\lambda t_{meas}))$; t_{irr}, t_{cool}, t_{meas}- irradiation, cooling and measurement time, respectively; λ - the decay constant of isomer to be investigated; *n*- number of nuclei present in a bremsstrahlung radiation beam; $D(E_{\gamma max})$ - doze obtained by a sample which is measureed by a tick-walled aluminium chamber [70]; N_{exp} - number of recorded pukses under total absorption photopeak of corresponding γ-quantum.

Integral cross-sections were calculated by the following equation:

$$\sigma_{\text{int}} = \int_{E_{thres}}^{E_{\gamma\max}} \sigma(E_\gamma)dE_\gamma = \frac{Y(E_{\gamma\max})(E_{\gamma\max} - E_{thres})F(E_{\gamma\max})}{\int_{E_{thres}}^{E_{\gamma\max}} W(E_{\gamma\max}, E_\gamma)dE_\gamma}, \quad (3)$$

where $W(E_{\gamma max},E_\gamma)$ - spectrum of a bremsstrahlung radiation with maximum energy $E_{\gamma max}$; E_{thres} - threshold of the reaction to the studied in present article it was equal to energy of first activation level for the corresponnding isomer; $F(E_{\gamma max})$- function of absolute chamber's response [70]. The specrtum of a bremsstrahlung

The results otained are given in Fig. 5. From Fig. 5. we see that an integral cross-section for ${}^{89}_{39}Y_{50}$ nuclei increases with energy increasing up to ~8.5 MeV, and then it comes to saturation begins to increase again.It means that a new activation level or a group of levels appear in this energy region through which the population of isomeric state of ${}^{89}_{39}Y_{50}$ nuclei takes place.

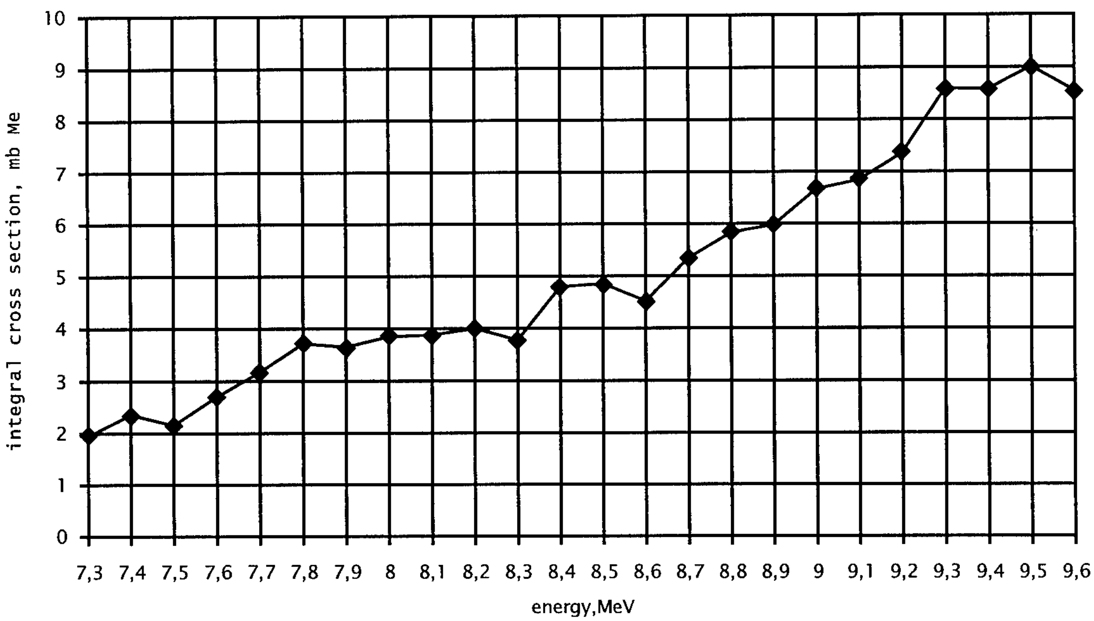

Fig.5. The integral cross section isomerical states excited in the (γ,γ') reaction

for nuclei ${}^{89}_{39}Y_{50}$.

3.2. CALCULATION OF ENERGY ACTIVATION LEVEL

Thus, the above speculations enable us to conclude that the activation level in the range of the excitation energies below 2.0 MeV is to be formed due to the one-nucleon transition in the framework of one upper unfilled nuclear shell, for the nuclei in question this being the 1f2p1g shell. These transitions will be referred to as those of type A (see fig.6).

Besides the transitions between the subshells of the same upper nuclear shell being filled to the neighbouring free nuclear shell (the energetic superimposement of those subshells can be determined from the stripping reactions), are possible. We refer these transitions to type B (see fig.7).

Let's consider proton E1-transitions from subshell of 1f2p1γ-shell of ${}^{89}_{39}Y_{50}$ nucleus to subshell of unfilled 3s2d1g1h shell. Such transitions will result in formation of a hole state at one of the subshells of the 1f2p1g shell, corresponding to the hole of the subshells of the 1f2p1g shell, corresponding to the hole state in an A-1 nucleus, being revealed in the pick-up reaction for the A ucleus, while at one of the subshells of the 3s2d1g1h-shell a partical state is formed, corresponding to the partial state of A+1 nucleus, being revealed in the stripping reaction for the A nucleus. The energy of such particle-hole state (1p-1h - state) can be determined from [71,72] by means of the expression:

$$E_{ph} = \varepsilon_p + \varepsilon_h + E_A - E_{A+1}\ , \qquad (4)$$

E_{ph} -energy 1p-1h - state; ε_h - the energies of hole state (these states are observed in proton pick-up reaction on nucleus A) to be formed in subshells from which the transition is effected; ε_p -the energies of partical states (such states are observed in poton stripping reaction on nucleus A with the formaation of nucleus A+1), formed by subshells to which proton transition is effected; E_A, E_{A+1} - binding energy of nuclei with mass number A and A+1.

Proton pick-up and stripping reaction in ${}^{89}_{39}Y_{50}$ nucleus have been studied in [73,74]. In accordance with the scheme of ${}^{89}_{39}Y_{50}$ nucleus level [57] the isomeric state of this nucleus is population through levels which are formed by $2d_{5/2}$ subshell.

In [73] in proton stripping reaction it is found that the states which are formed by $d_{5/2}$ subshell are concentred in the energy region near 6 MeV. The level with the energy of 5.64 MeV to be formed by $2d_{5/2}$ subchell is the largest spectroscopic factor. Proton E1-transitions the given subshell may be effected from $2p_{3/2}$ and $1f_{5/2}$ subshells. The data of this subshell from ^{88}Sr levels with the energies of 1.84 and 3.21 MeV which are observed in proton pick-up reaction, in ${}^{89}_{39}Y_{50}$ nucleus [74]. The difference in binding energies of ^{89}Y and ^{90}Zr nuclei is 1.3 MeV. For ε_h =1.84 MeV and ε_p =5.64 MeV, using expression (4) we have E_{ph}=8.76 MeV. So, the growth in cross-section which is observed beginning with the energy of ~8.5 MeV may be explained by proton transitions from $2p_{3/2}$, $1f_{5/2}$ subshells to $2d_{5/2}$ subshell.

${}^{109}_{47}Ag_{62}\ (\gamma,\gamma') \rightarrow {}^{109m}_{47}Ag_{62}$

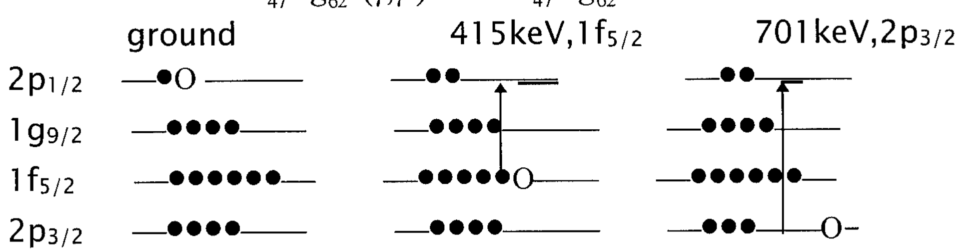

Fig.6. Scheme of one-nucleon transitions of tape A.

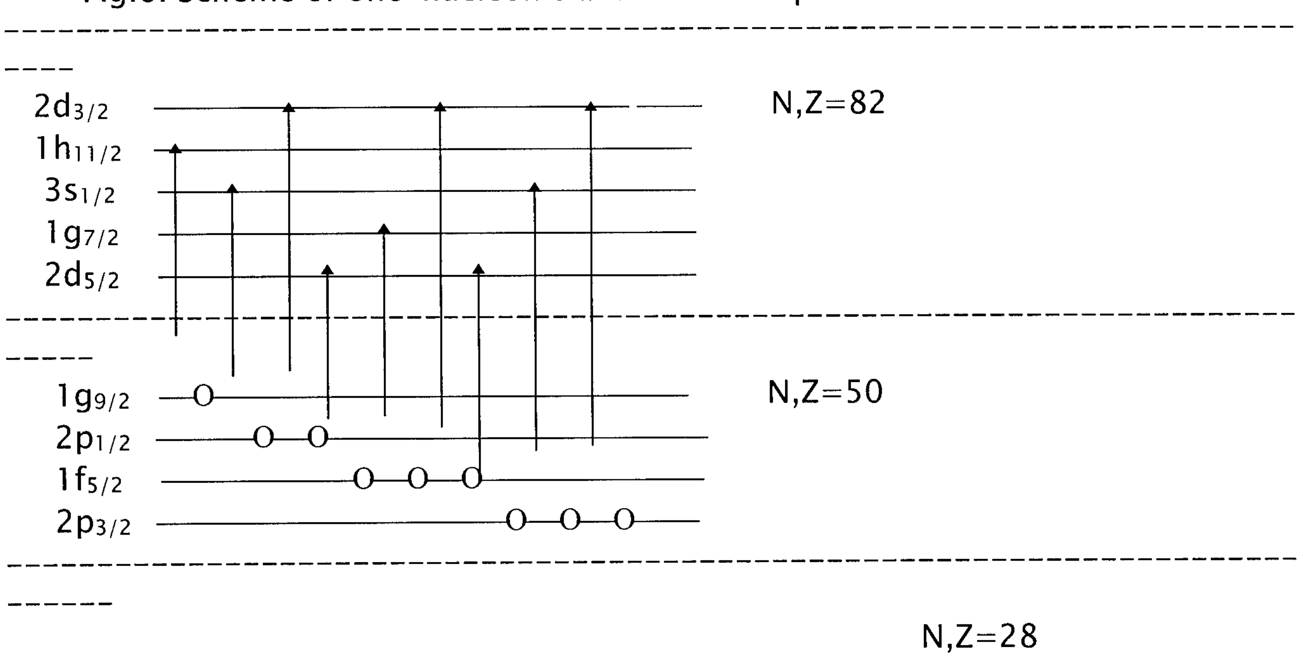

Fig. 7. Scheme of one-nucleon transitions of tape B.

CONCLUSION

Thus, the analysis of data on the activation levels of $^{107,109}_{47}Ag_{60,62}$, $^{111}_{48}Cd_{63}$, $^{113,115}_{49}In_{64,66}$ and $^{199}_{80}Hg_{119}$, nuclei and the usage of spectroscopic information about excited states of the given nuclei from one-nucleon transfer reactions allows one to get new information on the mechanism of activation level excitation.

Similar analysis for ^{77}Se and ^{87}Sr nuclei was carried out by the author earlier [53].

From fig.3 it is seen that ^{77}Se and ^{109}Ag nuclei have similar shell-like structure. The structure of metastable statesof these nuclei is also similar. These states are formed by 1g subshell and qudrupolar phonon of the core of these nuclei.

Similar situation is observed for ^{87}Sr and ^{115}In nuclei. These nuclei have isomeric states with similar shell-like structure (see fig. 3).

Not withstanding the fact that the nature of metastable states in ^{77}Se, ^{107,109}Ag,, ^{87}Sr, ^{113,115}In nuclei is different, the excitation mechanism of activation levels through which the population of metastable states of these nuclei takes place is similar. It means that the excitation of activation levels occurs mainly as a result of one-nucleon transition between subshells of the upper unfilled shell 1f2p1g.

The analysis of data for ^{115}In nucleus shows that shell-like structure of a nucleus is of great importance in the mechanism of the population of metastable states.

Experimental measurements of excitation cross-section of metastable state for ^{89}Y nucleus shows that within the region of 8.5 MeV one or a group of activation levels is observed. Such behaviour can be described in the approximation of one-proton transitions from 1f2p1g shell to 2d3s1g1h one.

^{199}Hg nucleus is very interesting in this regard as there are no experimental data about the levels through which the population of metastable levels may occur. However, activation levels are revealed by experiment which correlate with those to be observed in neutronic pick-up reaction. It may denote that the transition from these activation levels to isomeric level is effected by means of conversion electrones (internal conversion). The experimental finding of such conversion transition would give new information about the mechanism of the population of metastable states from activation levels.

It should be mentioned that for more detailed identification of activation levels the additional information about spectroscopic characteristics of nuclear levels from one-nucleon transfer reactions with the formation of $^{107,109}_{47}Ag_{60,62}$, $^{111}_{48}Cd_{63}$, $^{113,115}_{49}In_{64,66}$ nuclei is needef. The perspectives of the approximation as hole statees in core *Sn*

considered, are of great important. Analogous situation is observed for *Ag* nuclei where excited states may be considered as holes in core *Cd* and states of type "a particale with core *Pd*". In the case of the ground state of *Pd* nuclei the matching forces probably play a great role, because in this case subshell $2p_{1/2}$ reveals it self in proton pick-up and stripping reactions. Such behaviour of proton shell (Z=50) may be connected with the influenece of magic number N=64 [40].

The results obtained show the necessity of theoretical calculations in the approximation of one-nucleon transitions within the framework of shell-like models.

The experiments for more precise determination of energies of activation levels are necessary.

Three articles for publishing in journals are prepared on the materials of our report

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